MP-160
(Project 43.702)

[redacted]

~~CONFIDENTIAL~~

ECONOMIC INTELLIGENCE COMMITTEE
SUBCOMMITTEE ON TRANSPORTATION

REPORT OF THE

WORKING GROUP FOR THE STUDY OF RAIL LINE CAPACITY

TO THE SUBCOMMITTEE ON TRANSPORTATION

15 September 1955

AGREED METHODOLOGY FOR COMPUTING CAPABILITY OF RAILROAD LINES FOR THROUGH FREIGHT MOVEMENT

[redacted]

~~CONFIDENTIAL~~

[redacted]

TABLE OF CONTENTS

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

~~S-E-C-R-E-T~~ ~~CONFIDENTIAL~~

S-E-C-R-E-T

Page

~~S-E-C-R-E-T~~

~~CONFIDENTIAL~~

~~S-E-C-R-E-T~~ ~~CONFIDENTIAL~~

25X1

~~S-E-C-R-E-T~~ CONFIDENTIAL

ECONOMIC INTELLIGENCE COMMITTEE
SUBCOMMITTEE ON TRANSPORTATION

REPORT OF THE
WORKING GROUP FOR THE STUDY OF RAIL LINE CAPACITY
TO THE SUBCOMMITTEE ON TRANSPORTATION

15 September 1955

AGREED METHODOLOGY FOR COMPUTING CAPABILITY* OF RAILROAD LINES FOR THROUGH FREIGHT MOVEMENT

I. Introduction

The purpose of this paper is to present a methodology for computing the through freight-carrying capability of railroads under normal civilian operations over a long period of time such as a year or more. The formulas given here are an attempt to include all the major elements involved in line capability calculation. In view of the lack of intelligence on some of these factors for certain individual lines, tables and other information are presented which indicate general ranges for many of the factors so that, in the absence of data on one factor, the analyst can choose an estimated figure which is of approximately the proper magnitude for the type of line under consideration.

Limits on the capability of a line for through freight movement may be set by one or more of the following: (1) capability of the line itself; (2) capability of terminal and yard facilities; (3) capability of available rolling stock or motive power, (4) number and/or capability of the employees. It is assumed

---

* The term capacity, as used in this study, is defined as the theoretic maximum performance which could be attained by a given facility, provided all other contributing factors (such as locomotives, rolling stock, line and terminal facilities, personnel, weather, etc.) could be introduced into the system to an optimum degree. The term capability, as used in this study, is defined as the maximum performance which a line, facility or system can accomplish when the limitations of all contributing factors are considered.

~~S-E-C-R-E-T~~ CONFIDENTIAL

(See Basic Assumptions in II A below) that adequate numbers of qualified personnel are available, and therefore no methodology for this factor is included in this report. The effect on capability of the first three items is considered separately, and should be computed separately for each line. The results of these computations should then be compared, and whichever figure is lowest must be used as the through capability of the line.

NOTE: It is imperative that published figures on rail line capability include a statement of all the basic assumptions underlying the estimate. This is essential because major differences in capability estimates may result from differences in basic assumptions, even when the same formulas are used.

II. Methodology for Computing Through Capability of Railroad Lines

The through capability of a railroad line is normally expressed in terms of number of trains each way per day (EWPD) and the average net load of freight carried per train. This through capability is obtained by calculating the capability of the line itself, its yards, and its locomotive repair facilities and adopting the lowest of the three capability estimates.

A. Basic Assumptions for Computing Line Capability

The determination of line capability, utilizing the methodology presented below, is predicated on the following basic assumptions:

1) Adequate numbers of freight cars and locomotives are available (unless indicated otherwise by a computation of freight car and locomotives requirements).

2) Adequate numbers of qualified personnel are available.

[redacted]

3) Trains will not be bunched or "fleeted."

4) No priority by class will be given to any movement (i.e., passenger trains, if operated, will travel by freight train speeds; speed will generally be limited by the average speed of the heaviest trains run).

B. Methodology for Computing Maximum Train Density*

1. Single Track Lines

Use of the following formula is recommended for estimating the maximum train density of a single track railroad line in terms of trains EWPD (each way per day). This formula is intended to give the line capability only between major terminals. Methodologies for computing the capability of yard and locomotive servicing facilities are shown below, and the capability estimates derived from the application of these methodologies should be compared with the line capability estimate to determine whether through capability may be limited by yards or locomotive servicing facilities. The lowest of the three capabilities should be adopted as the line capability for through traffic.

$$MSTD = 1/2 \left(\frac{1440}{RT + DT} \right)$$

Where: MSTD = maximum single track train density, in trains each way per day. The term "trains each way per day" represents movement in one direction; the same figure is also applicable for movement in the opposite direction at the same time.

1/2 = factor for reducing two-directional operation to one directional.

* The Working Group considered several available formulas for computing maximum train density of railroad lines, and conducted an exhaustive study of each of the elements in these formulas. The formula recommended by the Working Group represents an integration of the best elements of the formulas studied, presented in a form which, it is hoped, is both simple and self-explanatory.

25X1

3

[redacted]

[redacted]

1440 = minutes per 24-hour day.

RT = running time between sidings in minutes. In this formula, the analyst should use the longest average running time which can be found between any two sidings on the line for which this computation is being made. Running time may be obtained by dividing distance between sidings by the average running speed (average speed from start to stop). When running time is calculated by this method, the result will be in terms of parts of an hour (such as 0.32 hours), which must be converted to minutes by multiplying by 60, since RT must be expressed in minutes. When RT is obtained by this method the limiting block will be the longest block.

DT = delay time, waiting for the opposing train, in minutes. DT = 1/2 RT. This time is assumed to be one-half the running time between sidings because while the opposing train will at times be waiting at a siding, and at other times will still be at the next siding, on the average under maximum operation it will be mid-way between the passing siding and the next siding (this time is intended to include delays caused by hot boxes and other mechanical failures).

Where average running speeds are not available to permit calculation of RT and of DT, it is recommended that the speeds shown in the tabulation below be used.* When more than one criterion is known for a line, the average speed chosen should be the lowest indicated by any one of the criteria. These speeds are averages between division points, and hence include all intermediate stops for passing. (In the calculation of line capability, no consideration is given to delay time in yards). When the selected speed is divided into the longest signal-to-signal distance,

---

* In the formula recommended, the effect of winter conditions, floods, accidents, and human error are included in the average freight train speeds. The effect of winter conditions on net freight train loads and on locomotive and freight car requirements are considered below. (Section II. D. 4, Net Freight Train Tonnage, page 17).

[redacted]

[redacted]

the total of RT plus DT will be found. The result will be in terms of parts of an hour, which should be converted to minutes by multiplying by 60.

Condition of Track	Type of Control	Maximum Grade (in %)	Average Speed * (in MPH)	(in km/hr.)
Exceptionally good	Automatic block	up to 1.0	9	14.5
Good to fair	Automatic block	1.0 - 1.5	8	12.9
Fair to poor	Automatic or manual block	1.5 - 2.5	7	11.3
Poor	Automatic or manual block	2.5 - 3.0	6	9.6

These speeds include the average effects of unusual delays resulting from human error, wrecks, floods, and snowstorms. These speeds can be used as a check on results obtained when RT and DT can be determined from available information.

2. Double Track Lines

Because double track lines generally have a capability considerably in excess of terminal and yard facilities it is necessary to calculate the capability of terminal and yard facilities on the line. The lower of these two figures should then be used as the double track line capability figure. ** (See Annex II for formulas which may be used for double track capacity).

C. Deductions from Line Capability to Obtain Capability for Through Freight Traffic

The capability of a line is the maximum total number of trains which can be handled over that line. However, to determine capability of a line for through freight train movements, it is necessary to deduct the following: (1) Trains carrying supplies for the operation and maintenance of the line, including fuel, rails, ties, and ballast. Although maintenance of a railroad line can be neglected for short periods of time, it is necessary to have continuous maintenance if a line is to be operated at its capability for a long period, as for a year or longer; (2) Work trains, snow plows, wrecking trains. These trains occupy the track, and may displace through trains; (3) Minimum essential passenger traffic for civilian and military movement; (4) Requirements of the economic and of military forces along the line, other than at its terminal.

* For electrified lines, add 2 m.p.h. (3.2 km/hr.) to this speed.

** It is assumed that winter conditions will not reduce the capability of double track lines in terms of trains EWPD. The effect of winter conditions on net freight train loads and on locomotive and freight car requirements are considered below.

~~SECRET~~

D. Methodology for Computing Net Tonnage per Freight Train Under Maximum Operation

To obtain net freight train tonnage, it is first necessary to compute the maximum gross freight train tonnage which will be permitted by each of the following factors: a) The locomotive or locomotives used; b) The shortest passing siding in use on the line; c) The strength of drawbar used on freight cars. The smallest of the three estimates resulting from these computations should be adopted as the maximum gross freight train tonnage under capacity operation.

1. Maximum Gross Freight Train Tonnage

a. Formula for Calculation of Gross Trailing Load

Gross trailing load, which is the maximum weight a locomotive is capable of pulling behind it under given conditions, is calculated by the following formula. This formula applies to all types of locomotives (steam, diesel-electric, and electric).

$$P = \left(\frac{TE}{Tr + Gr} - W \right) X\ 0.8$$

Where: P = gross tonnage pulled by the locomotive, in short tons (to convert to metric tons, multiply P by 0.907).

TE = locomotive tractive effort, at the rail, in pounds. If tractive effort is given at the cylinder, reduce to 80 percent to obtain tractive effort at the rail. If tractive effort is not given, see formula below (Section II. D. 1. e., Locomotive Tractive Effort), for calculating tractive effort. Tractive effort varies with train speed as follows:

Train Speed m.p.h.	Train Speed km./hr.	Percent of Rated Tractive Effort
0-10	0-16.1	100
12	19.3	98
16	25.8	95
20	32.2	90
24	38.6	83

Tr = train resistance (this factor is 4.2 pounds per ton at 10 mph and 6.0 pounds per ton at 20 mph; use 20 pounds per ton for starting).

Gr = grade resistance calculated by multiplying ruling grade* in percent by 4.2 pounds per ton at 10 mph or 6.0 pounds per ton at 20 mph.

W = weight of locomotive and tender (in working order) in short tons.

0.8 = efficiency factor to account for loss in efficiency under actual operation.

When calculating the maximum gross tonnage a locomotive is capable of hauling, computations must be made for two alternatives, (1) Ability of the locomotive to start the load, based on locomotive tractive effort at starting and (2) Ability to pull the load over the ruling grade, based on locomotive tractive effort at 16 mph.** The lower of these tonnage figures is

---

* Ruling grade is that grade on a section of line which limits train tonnage. The steepest grade on a line may not be the ruling grade if it is short, or occurs immediately after a steep down-hill grade which permits a train to gain momentum.

** The characteristics of the average locomotive are such that its greatest performance is reached at speeds of from 10 to 20 mph, the maximum being reached at about 16 mph. At a speed of 10 mph a steam locomotive can pull a heavier train than it can at 16 mph; however, at 10 mph the line capacity in trains EWPD is less than it is at 16 mph, due to the longer running time between sidings. Hence, when at 10 mph the heavier train tonnage is multiplied by the smaller number of trains, the resultant figure of gross tons EWPD is smaller than the figure derived at 16 mph.

the limiting factor and thus becomes the gross tonnage which the locomotive is capable of handling over a given line.

b. Determination of Average Freight Locomotive

Where data are available on the classes and/or types of freight locomotives in use on a specific line, weighted average tractive force of these freight locomotives can be determined. If such data are not available, a judgment will have to be made concerning the average tractive force of freight locomotives, based on available information such as data on the national freight locomotive park.

c. Locomotive Tractive Effort

1. Steam Locomotives

Tractive effort, which is the measure of pulling power of a locomotive, normally expressed in pounds may be computed by several formulas, each utilizing various specifications of the locomotive. Where accurate estimates of locomotive tractive effort are desired, and the information is available, the following formula may be employed:

$$TE = \frac{N}{2}\left(\frac{K \times Ps \times d^2 \times 8}{D}\right)$$

Where: TE = Tractive effort, at the rail, in pounds (to convert to kilograms, multiply TE by 0.454).

N = Number of locomotive cylinders.

2 = Factor to reduce to two cylinder unit.

K = Constant, based on error and percent of cutoff, as follows. Where data are not available on the figure to be used, it is recommended that the value of K be assumed to be .80.

Main Valve, Maximum Cutoff Percent	Value of K: Without Aux. Ports	Value of K: With Aux. Ports, 80% Min. Cutoff
90	.85	--
80	.80	.80
70	.74	.78
60	.68	.77
50	.60	.75

Cutoff is the cutting off of entry of steam into the cylinder before the stroke is completed, which permits steam expansion to complete the stroke. It represents the percentage of stroke through which steam is permitted to enter the cylinder.

Ps = Steam pressure in pounds per square inch.

d = Diameter of cylinders (high pressure or single) in inches.

S = Length of stroke of the piston in inches.

D = Diameter of drivers in inches.

Where data are limited, or a close approximation of tractive effort will suffice, the following formula for determining tractive effort at starting is recommended:

$$TE = \frac{W}{4}$$

Where: TE = tractive effort at the rail, in pounds (to convert to kilograms, multiply TE by 0.454).

W = weight on drivers. If this figure is not available, but total weight of locomotive and its wheel arrangement are known, W may be calculated from the following table:

~~S-E-C-R-E-T~~

Wheel Arrangement of Locomotive	Percentage of Weight of Drivers	Wheel Arrangement of Locomotive	Percentage of Weight on Drivers
0-4-0	100	2-8-2	73
2-4-0	80	2-8-4	61
2-4-2	57	4-8-0	80
4-4-0	67	4-8-2	67
0-6-0	100	4-8-4	57
0-6-2	75	0-10-0	100
2-6-0	86	0-10-2	83
2-6-2	67	0-10-4	71
4-6-0	75	2-10-0	91
4-6-2	60	2-10-2	77
0-8-0	100	2-10-4	67
0-8-2	80	4-10-0	83
0-8-4	67	4-10-2	72
2-8-0	89	4-10-4	62

To determine weight on drivers for wheel arrangements not shown, approximations may be made from the above tabulation.

4 = Coefficient of friction.

Where data only on heating surface are available, tractive effort can be computed from formulas found in standard steam locomotive textbooks.

ii. Diesel-Electric Locomotives

The tractive effort of a diesel-electric locomotive, unlike that of the electric locomotive which has practically unlimited power availability, is limited by the horsepower of the diesel prime mover. The diesel engine has a certain horsepower rating from which the tractive effort at any speed can be obtained by use of the following formula:

$$TE = \frac{hp \times 375}{v} \times 0.8$$

Where: TE = tractive effort in pounds (to convert to kilograms, multiply TE by 0.454).

hp = horsepower rating

375 = conversion factor obtained in converting horsepower to foot pounds per hour (60 x 33,000) and miles per hour to feet per hour (5280).

~~S-E-C-R-E-T~~

0.8 = efficiency factor, for current and transmission losses.

v = speed in miles per hour.

Whenever possible, diesel-electric locomotive tractive effort should be obtained from rating curves furnished by the manufacturer.

Diesel-electric locomotives are usually designed for factors of adhesion of 3.5 or less; therefore, the following formula can be used as an approximation. This approximation is for continuous operation at speeds of from 5 to 10 mph.

$$TE = \frac{W}{3.5}$$

Where: TE = tractive effort, in pounds (to convert to kilograms, multiply TE by factor of 0.454).

W = weight on drivers, in pounds.

3.5 = factor of adhesion.

iii. Electric Locomotives

The tractive effort for an electric locomotive is governed by the amount of power supplied to the motor and by the capability of the motor itself. It is obtained by equating work done at the rim of the driving wheels to the work produced by the motor torque in one revolution of the driving wheels. The following formula gives hourly tractive effort, which is equivalent to starting tractive effort.

$$TE = \frac{T \times 24 \times G \times E \times N}{D \times g}$$

Where: TE = tractive effort in pounds (to convert to kilograms, multiply TE by 0.454).

T x 24 = torque of a single motor in pounds (torque is taken at a 1-foot radius from the motor armature shaft center,) placing it on the circumference of a circle 24 inches in diameter.

G = number of teeth in the gear.

E = gear efficiency. When intermediate gearing is used this equals 96 to 97%; when no intermediate gearing is used, G/g x gear efficiency = unity.

N = number of motors.

D = driving wheel diameter.

g = number of teeth in the pinion gear.

There is a definite relation between torque, current, voltage, and speed. These relations are available in a series of characteristic curves furnished for each type of motor by the manufacturer. These curves are usually based on substation voltage. Because of transmission losses, it is recommended that trolley voltage be taken as 90 percent of the substation voltage, thus reducing the torque on the manufacturer's curve to 90 percent.

Where data are limited, or a close approximation of tractive effort will suffice, the following formula for determining tractive effort of an electric locomotive at starting is recommended:

$$TE = \frac{W}{A}$$

Where: TE = tractive effort in pounds (to convert to kilograms, multiply TE by 0.454).

W = adhesive weight in pounds.

A = factor of adhesion. See text below for figures to be used.

This formula provides an approximation only, and is not accurate either for hourly or continuous tractive effort. This approximation is for continuous operations at speeds of from 5 to 10 mph.

Torque and tractive effort increase with power input; but, although the power supply is, for practical purposes, unlimited, there are two important limitations on the tractive effort. 1) If the power exceeds the factor of adhesion, then slippage occurs between the drivers and the rail. Electric locomotives are generally designed for factors of adhesion from 4.3 to 2.8. A factor of 3 for US locomotives and 4 for European locomotives can reasonably be used for estimating purposes. 2) The heating of motors at full load and high current value. The heating does not occur at once; therefore, it is permissable to overload the motors for a limited period. Usually two tractive effort ratings are specified, the continuous and the hourly. It is dangerous to use the hourly rating for capability computations unless the situations of the ruling grades are known. The length of the grade and the existence of downhill grades to allow the motors to cool are important factors in the use of the hourly figure.

d. Effect of Use of Multiple Power

Two or more locomotives may be used on sections of a railroad line when the gross tonnage of through trains would be significantly reduced on a designated short helper section if only one locomotive were used.

i. Steam Locomotives

Tonnage over the ruling grade should be computed for one locomotive, and, if it is found that the ruling grade is far in excess of any other grade on the line, then the employment of two or more locomotives should be considered provided facilities to service the motive power are available.

Tonnage will then be determined over the second most difficult grade, employing one locomotive. As an example, a locomotive can pull only approximately half as much tonnage over a 1.25 percent grade as it can over a 0.5 percent grade. If a line has only one grade, or perhaps a few grades in the same area, of 1.25 percent, doubleheading should be considered over those grades. Doubleheading on 0.5 percent grades on other sections of the line would therefore be a waste of motive power. If, however, a grade of 1.25 percent was common throughout, this grade should become the ruling grade for a single locomotive, and thus determine the maximum tonnage throughout the line.

Under favorable conditions, the use of two locomotives (doubleheading or use of a pusher) will affect an increase in train tonnage of approximately 80 percent compared with the train tonnage when one locomotive is used. However, a detailed analysis should be made for ruling grades and caution must be exercised in using this factor.

Under certain circumstances it may be desirable to double-head trains over long sections of line where there is no single short ruling grade. The feasibility of such a practice as a means of obtaining a high net tonnage per train depends upon 1) the availability of sidings and yard tracks of sufficient length to hold a double headed, train, and 2) the capability of yard and locomotive servicing facilities to handle the increased number of cars and locomotives.

ii. Diesel-Electric and Electric Locomotives

When two or more diesel-electric or electric locomotives are employed to haul trains, the maximum gross train tonnage figure for one locomotive can be multiplied by the number of units employed.

2. Effect of Length of Sidings

In determining gross trailing load, consideration must be given to the length of sidings or passing tracks, since their length often limits the length of trains, and consequently the tonnage of trains. Certain available locomotives may be able to handle gross train loads of 2,000 tons on a given line, but if the length of the sidings will accomodate trains of only 1,500 tons gross load, tonnage will be limited by those sidings to 1,500 tons.

Train length may be calculated as follows: 1) Determine the approximate part of the gross train tonnage represented by empty cars. This is obtained by multiplying the percentage of empty cars in a train by the ratio between average tare weight of car and average gross tonnage per loaded car (average tare weight plus average net load per loaded car), and multiplying the result by the gross train tonnage. The figure used for percentage of empty cars in a train should reflect the actual types of traffic which will be moving in each direction when the line is being operated at its full capability. For example, if petroleum is expected to make up a large percentage of total traffic in one direction, it can be expected that almost all the tank cars will move empty in the opposite direction, and that the percentage of empty cars per train in that direction will be relatively high. The figure for average net tonnage per loaded car should also include the effects of actual traffic which will move, because load per car of military vehicles may be very low, while load per car of coal may be very high. 2) Divide the total tonnage of empty cars by the average tare weight per car. This gives average tonnage of empty cars by the average tare weight per car. This gives number of empty cars in the train. 3) Subtract the tonnage represented by empty cars from the gross train tonnage. The remainder is that part of gross train tonnage represented by loaded cars. 4) Divide the total gross tonnage represented by loaded cars by the average gross tonnage per loaded car. This gives the average number of loaded cars in the train. 5) Add the number of empty and loaded cars to obtain total cars in the train. These figures may have to be adjusted slightly because the method of obtaining the number of empty cars from gross tonnage shown above gives only a rough estimate. 6) Multiply the total number of cars in the train by average length per car to obtain total length of cars. 7) Add to the total length of cars the length of locomotive and tender, and caboose, if any.* 8) Add to this about 400 feet for clearance in the siding (200 feet on each end of the train).

---

* For example, assume the following:

> Gross trailing load of locomotive over the line, 1,200 tons.
> Average tare weight of cars, 12 tons.
> Average net load per loaded car, 15 tons.
> Average ratio of empty to total cars in the train, 20 percent.
> Average car length, 40 feet.

Then, using the methodology outlined above, the following calculations are made:

$20\% \times \frac{12}{12 + 15} = 9\%$ 1,200 gross tons x 9% = 108 tons in empty cars.

$\frac{108 \text{ tons}}{12 \text{ tons tare}}$ = 9 empty cars per train

1,200 tons gross - 108 tons = 1,092 tons in loaded cars

$\frac{1{,}092 \text{ tons}}{12 + 15}$ = 41 loaded cars   9 empty + 41 loaded = 50 cars per train

50 cars x 40 feet = 2,000 feet of cars per train (excluding locomotive and tender).

It should be noted that 9 empty cars equal 18% of the total train instead of 20%, and could be adjusted for greater accuracy. However, utilizing the 2,000 feet length of cars, and adding about 100 feet of length for locomotive and tender, plus about 400 feet for length of lead tracks into sidings, a total siding length of about 2,500 feet is required. If sidings are known to be limited to 1,700 feet, or 800 feet less than the length which the gross trailing load of the locomotive would permit, then the sidings could hold 20 cars less, or approximately 30 cars. In this instance, about 24 cars would be loaded, for a net load of 360 tons, and 6 would be empty. Adding 360 tons tare weight for the 30 cars would give a gross train weight of 720 tons, or 480 tons less than the 1,200 tons which the locomotive is capable of pulling.

3. Effect of Drawbar Strength*

To start a car from a stand-still may require up to thirty pounds of drawbar pull per ton of weight, or even more in extremely cold weather. However, total drawbar pull on the train is not calculated by multiplying total train tonnage by this figure, since a train with automatic couplers starts one car at a time as the locomotive takes up slack. Once a car is started, only about three pounds of pull per ton, if the weight is carried in a heavily loaded car, or something more than that for a ton in a car lightly loaded, will keep it moving on straight and level track. In the United States specifications of the Association of American Railroads for draft gear require a minimum of 150,000 pounds in tensile strength. In Europe, with predominantly hook and link type coupling, the standard drawbar strength averages from 130,000 to 140,000 pounds. Thus the combined tractive effort of the locomotives could in no event equal or exceed this strength without the train parting. Under normal operations it is unlikely that drawbar strength will exceed by the tractive effort of the locomotive, since a train heavy enough to approach the limits of drawbar strength would normally be too heavy for a locomotive to start.

4. Net Freight Train Tonnage

On a national basis, net freight train loads average between 36 and 61 percent of gross freight train load. Where precise information is not available on the types of commodities being moved on an individual line, for a fully loaded train net train load may be assumed to average between 55 and 60 percent of gross

---

* By drawbar strength is meant the strength of the complete draft gear assembly.

freight train load. However, wherever possible, an estimate should be made of the types and amounts of traffic which will move when a line is being operated to its full capability so that a more accurate estimate of the ratio between net and gross train tonnage can be made. The net train tonnage can then be calculated from gross train load by utilizing figures derived from the methodology shown above (II. D. 2, Effect of Length of Sidings). From this calculation can be determined the number of loaded cars per train which can be moved in each direction under maximum traffic conditions. The number of loaded cars per train is then multiplied by the net load per loaded car to determine net load per train. The net load per loaded car must be determined on the basis of the type of commodities being carried.

The net tonnages derived above are based on ideal weather conditions. For winter operations, however, reductions in net tonnage should be made as shown in the tabulation below, mean monthly temperature data for a point along the line should be utilized. The number of months falling in each temperature block should be multiplied by the percentage of reduction; the percentages should be totaled; and the total should be divided by 12 to obtain the average percentage reduction for the entire year. This reduction may not have to be made if siding and yard track lengths reduce gross train tonnage significantly below the level which the locomotives are able to perform. These reductions include the effects of snow and ice on locomotive and train operation, as well as the effects of temperature.

[redacted]

Reduction in Locomotive Tonnage in Low Temperatures

Temperature °F	Temperature °C	Percentage of Reduction in Locomotive Tonnage Rating
Above 30	Above - 1	0
29 to 20	- 2 to - 7	10
19 to 10	- 8 to - 13	20
9 to 0	-14 to - 18	30
-1 to -10	-19 to - 23	35
-11 to -20	-24 to - 29	40

(Source: The Alaska Railroad, Timetable No. 47, 12 June 1949, U).

E. Methodology for Computing Throughput Capability* of Terminal and Yard Facilities

1. Freight Car Facilities

a. Throughput Capability of Yards** (Classification, relay, and terminal)

(i) Methodology for Use When There is Sufficient Intelligence.

Where the intelligence warrants the following approach should be used:

(1) Classification Yards

(a) Determine the operating capacity in terms of the number of freight cars that can occupy the classification sections of the installation (excluding receiving and departure yards, etc.); i.e., the percentage of trackage of these sections that can be occupied by cars without impairing the classification function of the facility. This capacity is calculated by measuring the trackage in the classification sections of the yard, multiplying by a factor of .60 to .75 and

* Throughput capability of terminal and yard facilities is represented by the number of locomotives or cars which can pass through the facility in 24 hours.

** Figures of "number of cars handled" by a yard are often calculated by adding cars received plus cars forwarded, thus giving a figure which is twice the car throughput of the yard. It is important in capability calculation that throughput and not car handlings be used.

dividing by the average length of a freight car. If the yard is of modern design and if the installation is equipped with departure yards a factor of .75 should be used. If the yard is less efficient, a lower factor should be used; but this factor should never be less than .60.

(b) Determine the daily classification capability of the classification sections of the yard for all directions served by the installation in terms of number of cars per day. This capability can be determined by multiplying the operating capacity, derived as shown above, by the following factors:

(1) A factor of 2 to 3 for a hump yard. The factor of 3 should be applied to yards known to have a high capacity and/or known to have equipment that should facilitate high speed classification (electric switches, automatic retarders etc.). In other cases the factor of 2 should be used.

(2) A factor of 1 to 2 for a flat or gravity yard. The factor of 2 should be used if the yard is known to have a high capacity and/or known to have a layout that would facilitate high capacity classification; i.e., equipped with a receiving yard and other trackage that allows movement of switch engines and groups of cars engaged in classification without fouling running tracks, locomotive track leadouts, ladder tracks etc. In other cases the factor of 1 should be used.

(2) <u>Relay Yards</u>

(a) Determine the operating capacity in terms of the number of cars that can occupy the relay section of the yard; i.e., the percentage of the relay

[redacted]

yard trackage that can be occupied by cars without impairing the relay function of the facility. This capacity is calculated by measuring the trackage in the relay section of the yard, multiplying by a factor of .70 and dividing the result by the average length of a freight car.

(b) Determine the daily combined relay capability for all directions of the relay section of the yard. This capability is determined by multiplying the operating capacity of the relay section of the yard by a factor of 5.

(ii) Methodology for Use When Size of Sections of the Yard Cannot be Determined. In cases where not even a rough approximation of the size of the various sections of the yard can be determined the following method can be used to arrive at a less accurate estimate.

(1) <u>Classification and Relay Throughput of a Classification Yard, in All Directions</u>

(a) Determine the approximate trackage of the entire installation.

(b) Determine the operating capacity of the entire installation by multiplying the total trackage of the installation by a factor of .60.

(c) Determine the daily classification and relay capability of the yard by multiplying the operating capacity of the installation by the following factors:

(1) Not more than 2 for a known hump or gravity yard of high capacity.

(2) All other installations a factor of one.

(2) <u>Relay Throughput of Relay Yards</u>

(a) Determine the approximate trackage of the entire installation.

[redacted]

[redacted]

(b) Determine the operating capacity of the entire installation by multiplying the total trackage in the installation by a factor of .60.

(c) Determine the daily relay capacity of the yard by multiplying the operating capacity of the yard by a factor of 5.

The capabilities as calculated above must be checked against the ability of the facility or complex of facilities to offer engines for trains in all directions.

Notes: 1) In the case of relay yards, locomotive servicing and repair capability normally is the governing factor in determining facility capability.

2) In the instance where a yard serves more than one line, it is necessary to deduct from total yard throughput capability the estimated essential traffic requirements of lines other than the one under consideration. The remainder will then represent the portion of yard capability which can be devoted to the line in question.

b. Capability of Car Running Repair Facilities

Unless there is specific information to the contrary, it is assumed that the capability of car running-repair facilities equals the requirements for running repairs which would be placed on them by operating a line to its full capability, or that their capability will be increased to handle these requirements.

2. Locomotive Facilities

a. Steam Locomotives

Locomotive servicing and repair which are performed at a locomotive's home terminal within or in the vicinity of the roundhouses or

[redacted]

[redacted]

locomotive shed are the following:* 1) Servicing, performed each time a locomotive returns from a run. This includes cleaning the fire, lubrication, coaling, watering, taking sand, and turning. Servicing takes place outside the roundhouse, and normally takes 2 hours. 2) Running repairs performed in the roundhouse, including roundhouse inspection. These repairs are performed while the locomotive is still hot. The average time taken for such running repairs is about 4 hours, thus about 17 percent of a locomotive's time is spent in this type of repair if a locomotive performs one turnaround a day. 3) Boiler washing. This is performed when the boiler is cold, and includes repairs performed at this time. Boiler washes are performed approximately every 30 days, and require from one to three days; hence an average of 7 percent of the locomotive's total time is spent in boiler washing. 4) Medium repairs. These are periodic repairs occurring every 1 to 2.5 years, and requiring from 15 to 25 days to perform. Thus, approximately 5 percent of the locomotive's total time is spent in medium repairs. Medium repairs normally occur in roundhouses although some are performed in locomotive repair plants; hence, roundhouse stalls would be occupied for such repairs.

When a locomotive servicing and repair facility serves more than one line, it is necessary to deduct from the facility's capability the estimated number of locomotives required for essential traffic on lines other than the line under consideration. The remainder will then represent the portion

---

* In addition to servicing and roundhouse repairs, locomotives are given major repairs in locomotive repair plants. These occur every 3 to 5 years, and require an average of 30 days; hence about 2 percent of the locomotives are out of operation for such repairs at all times. Heavy repairs are included in factors used to determine locomotive requirements.

of the facility's capability which can be devoted to operating the line in question.

(i) Capability of Locomotive Servicing Area

The capability of a terminal to perform locomotive servicing may be estimated roughly by: 1) obtaining the static capacity of the servicing area (the combined length of tracks in the area where locomotives are serviced including ash pit area, ready tracks, coaling, watering and sand house areas) and 2) multiplying it by a turnover factor, based on the average time required to receive, service and inspect an engine including time taken for running repairs in the roundhouse. If specific information is lacking on the time required for these operations in either the installation under study or the country in which the installation is located, a factor of 4 may be used, since servicing and making running repairs in the roundhouse takes an estimated 6 hours which is one fourth of a day.

(ii) Capability of Locomotive Roundhouses and Sheds

To determine the home roundhouse of locomotives operating on a line an initial survey should be made of the rail net in the area to determine the locomotive sheds or roundhouses to which locomotives are assigned for boiler wash. If specific intelligence is lacking, it is possible to determine that a facility has this responsibility if: (1) Intelligence indicates that it is a locomotive depot or terminal capable of medium repair in volume. (2) It is the only such terminal in the area, particularly if it is centrally located.

Capability of locomotive roundhouses or sheds for

[redacted]

maintaining a pool of locomotives may be determined by using the following formula:

$$LRHC = \frac{NS}{PR}$$

Where: LRHC = locomotive roundhouse or shed capability for maintaining a pool of locomotives. This figure represents the total number of locomotives which can be supported by the roundhouse, including locomotives both on the line and in the roundhouse at any one time.

NS = number of stalls in the roundhouse or shed.

PR = percentage of locomotives in roundhouse repair at any one time (excluding heavy repair in locomotive factory), stated as a decimal (30 percent is stated as 0.30). When figures are not available for the individual facility or the country under consideration, a figure of 30 percent may be used. This is based on the percentage of a locomotive's time spent in the roundhouse, which is equal to the percentage of the total locomotive park which is in the roundhouse at any one time. These percentages are: running repairs, 17; boiler washing, 7; medium repairs, 5; total in roundhouse repairs, 29.

The figure derived for LRHC above should be compared with locomotive requirements for the section of line served by the roundhouse under consideration. The locomotive requirements which are derived as indicated below (Section III. B, Locomotives) are given as total requirements for the entire line, and also include locomotives out of operation for heavy repairs in locomotive repair factories. To convert these locomotive requirements to a figure comparable with LRHC above, the following steps are necessary: 2) Substitute the length of locomotive district for length of line in the formula for calculating locomotive requirements in Section III. B below. This will give locomotive requirements for the locomotive district under

[redacted]

[redacted]

consideration. b) Deduct 2 percent from the resulting figure for locomotives in heavy repair shops.

If the comparison of locomotive requirements and roundhouse capability shows that requirements are slightly in excess of capability, emergency measures may eliminate the difference. A significant excess of requirements over capability, however, indicates that the roundhouse would prevent full line capability from being achieved, and line capability would have to be reduced to approximately the level which would be permitted by the roundhouse capability.

A check of the capability of roundhouses or locomotive sheds may be made by utilizing the following methodology.

(1) Determine the percentage of locomotive assigned to

[redacted]

from line formula. Furthermore, the percentage of locomotives in boiler wash and medium repair is always a minority of the motive power, thus the error is further reduced. In addition, when the final check on the motive power is completed, any error in the estimate will show up and the figures can be readjusted (usually by only a locomotive or two) to have a realistic balance between locomotives assigned to a terminal and those in for boiler wash and medium repair.

(3) Multiply the factor in (1) by the number of locomotives in (2).

(4) Determine the number of stalls available for the normal running repairs of the locomotives using this terminal, by subtracting the number of stalls occupied for medium repair and boiler wash from the total stalls available at this and all other locomotive sheds. The number of locomotives requiring running repairs in these engine sheds can be determined by a method similar to that used for medium repair and boiler wash. The percentage of locomotives continually in running repair is reflected in the percentage of time each engine spends in running repair each year, as indicated in national statistics, specific intelligence regarding the installation in question, or comparable statistics from another country.

(5) Determine the number of active locomotives that can be supported by the running repair capability, reflected in the number of stalls available, by inversely applying the percentages mentioned above. This number of locomotives indicates the number of engines available to support the trains in the "pipeline."

(6) Deductions must also be made for yard locomotives.

(a) The inspection and repair rate of these engines varies from the road engines but statistics on these engines can be obtained in the same manner as the data on the road engines.

[redacted]

(b) The number of yard engines assigned to the terminal under study for boiler wash and medium repair can be determined by examining the area served by the terminal under study for number of yards and type and size of railroad operation carried on; i.e., intensive industrial complex traffic, light agricultural traffic, etc.

(c) The number of yard engines that will be in the terminal under study for boiler wash, medium and running repair can be determined by applying the percentages arrived at above to the park of yard locomotives.

(7) The resultant figure is the capability of the roundhouse in terms of the number of road locomotives which can be offered daily by the roundhouse. This figure should be compared with capability of the line in trains each way per day multiplied by two. If the roundhouse capability figure is below the figure obtained by multiplying line capability by two, then line capability should be reduced to agree with the former figure.

b. Diesel-Electric and Electric Locomotives

Since very little servicing and running repair is required of diesel-electric and electric locomotives it is assumed, unless there is evidence to the contrary in specific cases, that facilities for these types of locomotives are adequate, or can be expanded relatively quickly to meet demands which would be placed on them by locomotive requirements resulting from operating a line to its capability. Diesel-electric locomotives require one to three hours for inspection, repair, refueling and sanding at the end of each trip; they are generally fueled only every third day. Electric locomotives require about one hour for inspection and servicing at the end of each trip.

[redacted]

III. Number of Freight Cars and Locomotives Necessary to Operate a Line at Full Capability

A. Freight Cars

1. Capability Formula

Determination of the total number of freight cars necessary to operate a line at its full capability may be used through the use of the following formula:

$$CR = TEWPD \times CPT \times RTT \times RF$$

Where: CR = car requirements for operating a line at its full capability, in number of cars.

TEWPD = number of freight trains each way per day as determined from line capability. This figure represents number of trains in one direction only.

CPT = number of freight cars per train. Method of determining this figure from gross train tonnage capability is shown above (Sections II. D. 1 and 2, Maximum Gross Freight Tonnage, and Effect of Length of Sidings).

RTT = round trip time, in days. This is the average time required for a car to move from average point of origin to average point of destination and return, including loading and unloading time. Calculation of RTT is shown below (Section III. A. 2, Round Trip Time).

RF = repair factor which is included to add the necessary number of cars out of operation for repairs. It is calculated by adding 1.00 to the percentage out of operation for repairs (thus, if 5 percent, or .05 are out of operation for repairs, the factor is .05 plus 1.00, or 1.05). On a national basis, the percentage of freight cars out of operation for repairs ranges upward from 2 percent. (During 1943 and 1944, the US railroads had 2.7 percent out of operation for repairs). Such a low figure can usually be sustained for a short period of time by deferring maintenance, but must then generally increase. (In 1946 and 1947, U.S. railroads had a figure of 4.2 percent).

[redacted]

[redacted]

When total freight car requirements have been thus determined, it may be necessary to comare these requirements with the total freight car park available to the railroad system, to determine what percentage of the total freight car park would be required for operating at full capability the line or lines under study (as calculated in Section III. A, Freight Cars). In some cases, these total requirements may be so large as to prevent the movement of essential traffic on other lines. In that event, capability of lines under consideration might have to be reduced to permit essential traffic movements on other lines.

2. Round Trip Time Formula

Round trip time is the average time between the departures of a loaded car from its average point of origin and the return of this or an equivalent car to the average point of origin. This time is not the same as turnaround time, which is the average time from one loading of a car to its next loading. Round trip time is determined by the following formula.

$$RTT = \frac{2 \times ALH}{CS} + \left(\frac{LUT}{24} \times LF\right)$$

Where:
- RTT = round trip time, in days.
- 2 = factor for obtaining length of car trip in both directions.
- ALH = average loaded haul of cars moving on the line under consideration, in the direction of the longest and largest loaded haul, in miles. This figure is determined by estimating the average points of origin and destination of major commodities participating in this movement and calculating weighted average haul. This includes local car movements on the line.
- CS = freight car speed, in terms of average distance moved per day in miles, from point of origin to point of destination and vice versa, including all intermediate stops, but excluding loading

[redacted]

and unloading time and switching to and from loading and unloading points. For normal movements, the speed of movement may average from 90 to 135 miles per day or 3.8 to 5.6 m.p.h. (144 to 216 kms. per day or about 6 to 9 km/hr.). However, on long-haul through movements, which involve a minimum of reclassification enroute, the average speed of movement may be as high as 225 miles per day or 9.4 m.p.h. (360 kms. per day or about 15 km./hr.).

LDT = average loading plus unloading time, in hours, including switching to and from loading and unloading points. Under capability operations this factor may vary from 48 to 72 hours, total for loading plus unloading, depending on the type of commodity (bulk items, such as coal and grain can be handled quickly), availability and skill of manpower, and availability of mechanical unloading facilities.

24 = factor to convert hours to days.

LF = loading factor to account for additional loading and unloading time taken by those cars which move loaded in both directions, and therefore have two loadings and unloadings instead of only one. This is determined by calculating the ratio of cars which move loaded in both directions to the total loaded car movement on the line (cars moving loaded in only one direction plus cars moving loaded in both directions) and adding 1.00. As an example, if 500 cars moved loaded in both directions and 2000 moved loaded in only one direction then the total loaded movement would be 2500, and the ratio would be 500 divided by 2500 which is 20 percent or .20. The loading factor used would, therefore, be 1.20 (.20 plus 1.00). If on a given line, all loaded cars are moving in one direction and all returning cars are empty, the factor would be 1.00; if all cars moved loaded in both directions the factor would be 2.00.

B. Locomotives

The number of locomotives necessary for operating a line at its full capability may be calculated by use of the formula shown below. The effects of winter weather conditions on locomotive requirements are reflected in the average net train load, which has been reduced for winter operations (Section II. D. 4, Net Freight Train Tonnage), and thus balances the increased difficulty of operating locomotives in winter.

$$LR = \left(\frac{(TEWPD \times 2) \times DHF \times LL}{AR} \times RF \right) + SLR$$

Where:

LR	=	locomotive requirements for operating the line at its capability, in number of locomotives.
TEWPD	=	trains each way per day, as determined from the line capability.
2	=	factor for obtaining total number of trains for the two directions combined.
DHF	=	double heading factor. When all trains have only one locomotive each, this factor will be 1.0, if all trains have two locomotives each, this factor will be 2.0.
LL	=	length of the line for which capability and locomotive requirements are being calculated in miles. To obtain a more accurate estimate of locomotive requirements it is suggested that this calculation be made for each locomotive operating division, and then totaling requirements for individual operating divisions to obtain requirements for the entire line.
AR	=	average run per operable road locomotive per day in miles. If the average mileage per road locomotive per day (which includes all locomotives, whether operable or not) is available, then RF should be omitted from the formula. If data for AR are not available for the line under consideration, national figures can be used. However, when a line is being operated at its capability and is hauling a maximum number of through freight trains which originated and/or terminate on other lines, the ratio of through trains to total trains will be greater than the national average, and thus the average mileage per operable road locomotive per day may be somewhat higher.

[redacted]

Where data are not available, it can be assumed that locomotives will operate 10 hours per day. This figure, multiplied by the average train speed on this line (as given above under II. B. 1 for single track lines, and in Annex II, Part B for double track lines) will give average daily run.

RF = repair factor. This is calculated by adding 1.00 to the ratio of locomotives out of operation for repair (other than running repairs) to total locomotive park. If adequate data are not available, the following ratios may be used: steam, 0.15; diesel-electric, 0.02; electric, 0.04. For example if the ratio is 0.15, then this added to 1.00 would give a repair factor of 1.15.

SLR = switch locomotive requirements. These are calculated by using the following table of requirements:

Location	Switch Engines Required
Major terminal with loading, unloading and classification functions	1 per 50 cars dispatched per day
Intermediate division terminals (minor classification)	1 per 150 cars passing through per day (each direction)
Railhead or unloading terminal	1 per 100 cars dispatched per day

IV. System Capability

The term "system capability" is intended to mean the capability of the entire railroad system of one country. Probably in every country in the world the combined capability of the individual railroad lines is considerably greater than the total capability of the freight car or locomotive parks. Therefore, while it may be possible to operate certain lines at their capability (sometimes at the expense of normal traffic on other lines because such an operation would require shifting locomotives and freight cars to the lines being operated at capability), it is impossible to operate all lines at capability concurrently.

[redacted]

[redacted]

Since the system capability of a country's railroads is limited by either the freight car park or the locomotive park, or both, the methodology shown below will permit the calculation of the capability of these parks. To determine which of the two parks is the more limiting factor with respect to capability, their total capabilities (expressed in terms of common measure) should be compared. To determine whether operating a particular line or lines at their capability will place an inadmissible burden on the freight car or locomotive parks, the requirements for this operation should be compared with total system capability.

a. Freight Cars

Capacity and capability of the total freight car park may be expressed in five ways: as static capacity, and as capability in carloadings, tons originated, net ton-miles, and gross ton-miles. To derive car capability figures, it is best to utilize data for performance under a long period of emergency. These data may be for the country under consideration or for comparable countries.

1) Static Capacity

This is derived by multiplying the number of each type of freight car by the average capacity (in short tons or metric tons) of that type of car, and totaling the resultant capacities. The weighted average capacity per freight car can then be obtained by dividing static capacity by the total number of cars. This figure is useful primarily in calculating the ratio between average net carload and average freight car capacity (in short tons or, metric tons).

[redacted]

2) Capability in Terms of Carloadings

The following formula may be used for calculating capability in terms of average daily carloadings. To convert to annual carloadings, multiply by 365 days.

$$ADC = \frac{CP - RC}{TAT}$$

Where: ADC = average daily carloadings.

CP = total freight car park.

RC = average daily number of freight cars out of operation for repairs.

TAT = freight car turnaround time, in days. This is the average time from one loading of a freight car to its next loading, including loading time, loaded haul, unloading time, and empty haul (if any), up to the beginning of the next loading. For method of calculating turnaround time, see below (Section IV. A. 6, Formula for Calculating Freight Car Turnaround Time).

3) Capability in Terms of Tons Originated

The following formula may be used for calculating capability in terms of average daily tons originated. To convert to tons originated per year, multiply by 365 days.

$$DTO = \frac{CP - RC}{TAT} \times TPC$$

Where: DTO = average daily tons originated, in short tons (to convert to metric tons, multiply by a factor of 0.91).

CP = total freight car park

RC = average daily number of freight cars out of operation for repairs.

TAT = freight car turnaround time, in days. This is the average time from one loading of a freight car to its next loading, including loading time, loaded haul, unloading time, and empty haul (if any), up to the beginning of the next loading. For method of calculating turnaround time, see below (Section IV. A. 6, Formula for Calculating Freight Car Turnaround Time).

TPC = average net load per loaded car, in short tons.

4) Capability in Terms of Net Ton-Miles

Net ton-miles are derived by multiplying tonnage of freight originated by the average distance the freight is moved. Net ton-miles per day may be calculated by using either of the following formulas. To obtain net ton-miles per year, multiply this figure by 365 days.

$$\text{NTM} = \text{ADC} \times \text{TPC} \times \text{ALH}$$

$$\text{NTM} = \text{DTO} \times \text{ALH}$$

Where: NTM = average daily net ton-miles per day, in short ton-miles (to convert to metric ton-kilometers, multiply this figure by a factor of 1.46).

ADC = average daily carloadings.

TPC = average net load per loaded car, in short tons.

ALH = average length of loaded haul of the freight car, in miles.

DTO = average daily tons originated, in short tons.

5) Capability in Terms of Gross Ton-Miles

Gross ton-miles are derived by adding the weight of the freight to the weight of the freight car and multiplying the total by the average distance moved by the freight, and adding this product to the weight of freight cars moving empty multiplied by the average distance moved by empty cars. To obtain gross ton-miles per year, multiply this figure by 365 days.

$$\text{GTM} = (\text{ADC} \times [\text{TPC} + \text{TW}] \times \text{ALH}) + (\text{AEC} \times \text{TW} \times \text{AEH})$$

Where: GTM = average daily gross ton-miles, in short ton-miles (to convert to metric ton-kilometers, multiply this figure by a factor of 1.46).

ADC = average daily carloadings.

[redacted]

TPC = average net load per loaded car, in short tons.

TW = average tare (empty) weight of the car, in short tons.

ALH = average length of loaded haul of the freight car (normally called "average length of haul"), in miles.

AEC = average number of empty cars moving per day. This may be calculated by multiplying ADC by the ratio of empty to loaded car miles. This ratio ranges from 35 to 55 percent.

AEH = average length of empty haul of freight cars between loaded movements, in miles. This may be calculated by multiplying ALH by the ratio of empty to loaded car miles. This ratio ranges from 35 to 55 percent (derived from the fact that the ratio of loaded to total car miles is 63 to 74 percent).

6) <u>Formula for Calculating Freight Car Turnaround Time</u>

The following formula may be used for calculating freight car turnaround time:

$$TAT = \frac{ALH + AEH}{CS} + \frac{LUT}{24}$$

Where: TAT = freight car turnaround time, in days. This is the average time from one loading of a freight car to its next loading, including loading time, loaded haul, unloading time, and empty haul (if any), up to the beginning of the next loading.

ALH = average loaded haul of all freight cars, in miles.

AEH = average empty movement of freight cars, between loaded movements, in miles.

CS = average freight car speed, in terms of average distance moved per day, in miles, from point of loading to point of next loading, including all intermediate stops, but excluding loading and unloading time and switching to and from loading and unloading points. For normal movements, the speed of movement may average from 90 to 135 miles per day, or 3.8 to 5.6 m.p.h. (144 to 216 km. per day or about 6 to 9 km./hr.). However, on long-haul through movements, which involve a minimum of reclassification enroute, the average

[redacted]

speed of movement may be as high as 225 miles per day, or 9.4 m.p.h. (360 km. per day, or about 15 km./hr.).

LUT = average loading plus unloading time, in hours, including switching to and from loading and unloading points. Under capability operations this factor may vary from 48 to 72 hours (total for loading plus unloading), depending on the type of commodity (bulk items, such as coal and grain, can be handled quickly), availability and skill of manpower, and availability of mechanical unloading facilities.

B. Locomotives

Total capability of the locomotive park may be expressed in terms of total tractive effort, net ton-miles, gross ton-miles, and gross and net tonnage per train. In making a locomotive capability estimate it is best to utilize data of performance under a long period of emergency. These data may be for the country under consideration or for a comparable country.

To determine the maximum freight carrying capability of a locomotive park it is necessary to utilize both freight and passenger locomotives. Utilization of all passenger locomotives for moving freight trains, however, would eliminate all passenger traffic. In addition, the operating characteristics of passenger locomotives are such that they would pull relatively short freight trains which would reduce average net tonnage per freight train.

1) Total Tractive Effort

This figure is expressed in terms of pounds of total tractive effort, and may be obtained by totaling the tractive efforts of all individual locomotives. In making capability estimates it is useful to calculate the weighted average tractive effort of locomotives for capability operation on an individual line.

2) <u>Capability in Terms of Net Ton-Miles</u>

Capability of road locomotives (this excludes switch locomotives) in terms of net ton-miles per day may be calculated by using the following formula. To convert to annual capability multiply this figure by 365 days.

NTM = (LP - RL) x DHF x NTPT x LR

Where: NTM = average daily net ton-miles in short ton-miles (to convert to metric ton-kilometers multiply this figure by a factor of 1.46).

LP = total number of road locomotives, excluding switch locomotives.

RL = average daily number of locomotives out of operation for repairs.

DHF = double-heading factor, the ratio of double-headed trains to total trains. If all trains are pulled by only one locomotive each, this factor is 1.0; if all trains are pulled by two locomotives each, this factor is 2.0.

NTPT = net tonnage per freight train, in short tons.

LR = average daily run per operable locomotive, in miles.

3) <u>Capability in Terms of Gross Ton-Miles</u>

Capability of road locomotives in terms of gross ton-miles per day may be calculated by use of the following formula. To convert to annual capability, multiply this figure by 365 days.

GTM = (LP - RL) x DHF x GTPT x LR

Where: GTM = average daily gross ton-miles, in short ton-miles (to convert to metric ton-kilometers, multiply this figure by a factor of 1.46).

GTPT = gross tonnage per freight train (weight of cars and their contents), in short tons.

All other elements of the formula are the same as for net ton-miles capability.

4) <u>Capability in Terms of Gross and Net Train Tonnage</u>

This figure may be obtained by using the formula shown above

~~S-E-C-R-E-T~~

(Section II. D. 1, Maximum Gross Freight Train Tonnage), and inserting into this formula the average ruling grade for the country under consideration, and the weighted average locomotive tractive effort. The resultant figure of maximum average gross freight train tonnage can be converted into net tonnage per freight train by utilizing the national average ratio of net to gross tonnage per train.

Next 5 Page(s) In Document Exempt